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CLINICAL RESEARCH

Clinical outcomes and costs of conventional and digital complete dentures in a university clinic: A retrospective study

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ABSTRACT

Statement of problem. Scientific data analyzing the clinical outcomes and costs of complete dentures fabricated by using conventional and computer-aided design and computer-aided manufacturing (CAD-CAM) processes are lacking.

Purpose. The purpose of this retrospective study was to compare the treatment duration, financial costs, and postdelivery adjustments of CAD-CAM and conventional removable complete dentures.

Material and methods. Thirty-two edentulous participants (16 women, 16 men; age 35-85 years) who had received either CAD-CAM (n=16) or conventional (n=16) maxillary and mandibular removable complete dentures provided by prosthodontists with a minimum of 2 years of experience were evaluated. The CAD-CAM denture systems were either DDS-AV (AvaDent Digital Dental Solutions) (n=11) or DD-IV (Wieland Digital Denture) (n=5). The total treatment period (days) was recorded at 3 different time points (T0: preliminary alginate impression; T1: denture delivery; T2: last scheduled postdelivery adjustment). Adjustments during the follow-up (after T2) were noted and included the removal of areas of excessive pressure, relining, or repairs. The costs of the dental treatment and the laboratory fees were calculated. The Wilcoxon rank sum tests were used for statistical analysis (α=.05).

Results. No statistically significant difference regarding the treatment duration between digitally and conventionally fabricated removable complete dentures was found: T_0-T_1 (P=.889); T_1-T_2 (P=.675); T_2- T_3 (P=.978). No significant difference was found in the number adjustments for areas of excessive pressure, relines, or repairs (P=.757, P=1.000, P=1.000) during the period. Laboratory costs of CAD-CAM removable complete dentures were significantly lower than those of conventional removable complete dentures (P<.001), but clinical fees were similar between groups (P=.596), resulting in a reduction in the overall total costs for the CAD-CAM removable complete dentures (P=.011). Regarding the number of clinical visits, neither the group (conventional/CAD-CAM (P=.945)/DDS-AV/DD-IV [P=.848]) nor the interaction group (conventional/CAD-CAM and DDS-AV/DD-IV)/period (P=.084/P=.171) showed any significant differences.

Conclusions. CAD-CAM removable complete dentures can be considered a viable alternative to conventional removable complete dentures regarding treatment duration, clinical and follow-up visits, adjustments, and maintenance requirements. (J Prosthet Dent 2022;128:390-5)

Dentistry continues to evolve in terms of dental materials, equipment, and techniques.[1] Although computer-aided design and computer-aided manufacturing (CAD-CAM) techniques are well established and widely used in fixed prosthodontics,[2] they are less commonly used to fabricate removable complete dentures (RCDs).[3-5] However, several commercial systems for CAD-CAM RCD fabrication have been introduced,[6] including AvaDent Digital Dental Solutions (Global Dental Science), Ceramill Full Denture System (Amann Girrbach AG), Baltic Denture System (Merz Dental), DENTCA (Whole You), Pala Digital Dentures (Kulzer GmbH), Wieland Digital Denture (Ivoclar AG), and Zirkonzahn Full Denture (Zirkonzahn).

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Clinical Implications

Computer-aided design and computer-aided manufacturing removable complete dentures seem to be beneficial when compared with conventional removable complete dentures with regard to laboratory and overall costs.

The AvaDent Digital Dental Solutions (DDS-AV) system provides clinicians with RCDs fabricated by a subtractive milling process during a 2-appointment protocol. The maxillomandibular relation is recorded with an anatomic measuring device. Although the accuracy and feasibility of using intraoral scanners for digital complete arches has been reported, intraoral scans are not routinely used to fabricate CAD-CAM removable complete dentures.[7-9] Therefore, the processes of impression making and jaw relation recording are similar to those performed in conventional RCD fabrication, while the technical manufacturing procedure in the dental laboratory is performed by using digital techniques.[7,8] The Wieland Digital Denture system (DD-IV) involves 4 clinical steps, including 1 optional clinical denture evaluation session. The maxillomandibular relations is recorded with intraoral gothic arch tracing.[10]

Conventional methods of fabricating RCDs usually include 5 to 6 clinical visits for impression making, maxillomandibular relation recording, and clinical evaluation.[11] Hence, CAD-CAM RCDs may be delivered more quickly with fewer visits.[7,12,13] Furthermore, CAD-CAM denture fabrication techniques may offer clinical and material advantages, including digital archiving,[14] improved fit,[15] better material properties,[16] and improved retention.[17]

Factors, influencing a patient's treatment choice include treatment duration and cost.[2,18] However, studies comparing the clinical outcomes and costs between conventional and CAD-CAM RCDs are sparse.[12,14,18,19] Therefore, the purpose of this study was to retrospectively evaluate and compare the patients' burden for CAD-CAM and conventional RCD fabrication by a specialized prosthodontist experienced in both CAD-CAM and conventional denture fabrication procedures. The null hypothesis was that no difference would be found between CAD-CAM and conventional RCD manufacturing in terms of treatment duration, treatment cost, and the need for postdenture delivery modifications.

MATERIAL AND METHODS

The Ethics Committee of the Canton of Bern, Bern, Switzerland, approved the retrospective analysis of patient records (KEK, Basec Nr. Reg-2016-00244), and all patients signed the respective consent form. The data were collected from the clinical records of patients whose RCDs were provided at the Department of Reconstructive Dentistry and Gerodontology, School of Dental Medicine, University of Bern, Switzerland, between August 2015 and August 2019 by experienced prosthodontists. Thirty-two edentulous participants (16 women, 16 men; age 35-85 years) were included. In the CAD-CAM denture group, participants who had received maxillary and mandibular RCDs were included (Table 1). In the conventional denture group, the data of individuals, matched for sex, age (within 5 years), and intraoral status (with or without oral cancer) who had also received maxillary and mandibular RCDs were obtained. The CAD-CAM denture fabrication systems were either DDS-AV or DD-IV. The records of patients who had received RCDs only in the maxilla or mandible or when the data of matching individuals were not available were excluded from the analysis.

The overall treatment period was divided into 3 parts: (T_0-T_1), production (preliminary irreversible hydrocolloid impression to denture delivery); (T_1-T_2), postdelivery (denture delivery to last intentionally scheduled postdelivery adjustment); (T_2-T_3), recall (last intentionally scheduled postdelivery adjustment to the last patient follow-up until August 2019). The overall treatment duration in days, including T_0-T_1 and T_1-T_2, as well as both periods separately, was analyzed.

The postdelivery adjustments comprised the removal of areas of excessive pressure, denture relining, or repairs. The number of all adjustments during all periods was calculated.

The costs were divided into dental treatment costs, dental laboratory costs, and total costs. Total costs included the sum of all treatment and laboratory costs. Dental treatment costs included the dentist's fees and the materials used during T_0-T_1 and T_1-T_2. All RCDs were fabricated in the same dental laboratory to standardize the quality and costs (the laboratory declared no conflict of interest with any of the companies involved in the fabrication of the dentures). The laboratory costs were calculated based on the final dental laboratory invoice.

For descriptive analyses, median values and interquartile ranges (IQRs) were calculated. The participants in the conventional and CAD-CAM groups were not matched individually (by sex, age, status, and so on), but the overall distribution of the studied population was matched for each group. Nonparametric tests (Wilcoxon rank sum tests) were applied to compare the treatment duration, number of adjustments (removal of areas of excessive pressure, relines, and repairs) during all periods, and financial costs between digital and conventional RCDs. All statistical analyses were performed with a statistical software program (IBM SPSS Statistics, v24.0; IBM Corp) (α=.05).

Table 1. Comparison of conventional and digital RCDs in terms of treatment duration (days) (median; IQR days) and number of adjustments during follow-up (median times; IQR)

Denture Design	Period 1 (*Production*): T_0-T_1 Preliminary Alginate Impression – Denture Delivery	Period 2 (*Post Delivery*): T_1-T_2 Denture Delivery – Last Postdelivery Adjustment	Period 3 (*Recall*): T_2-T_3 Preliminary Irreversible Hydrocolloid Impression – last Postdelivery Adjustment	Areas of Excessive Pressure removal	Relining	Repairs
Conventional complete RCD	49; 31.25	50; 27.5	70; 39.75	0.0; 1.25	0.0; 0.0	0.0; 0.0
Digital complete RCD	10; 32	11.5; 18	69; 42.25	0.0; 0.25	0.0; 0.0	0.0; 0.0
P	.889	.675	.978	.757	1.000	1.000

RCD, removable complete denture.

RESULTS

The records of 32 participants who had received either CAD-CAM–manufactured (n=16; 8 men and 8 women; median 68.0 years, IQR 23.0) or conventional RCDs (8 men and 8 women; median 60.5 years, IQR 11.5) were investigated. Seven participants had been treated for oral cancer in each group. In the CAD-CAM denture group, there were 5 with squamous cell carcinoma, 1 with laryngeal carcinoma, and 1 with oropharyngeal carcinoma. In the conventional group, there were 7 with squamous cell carcinoma and 4 of these with osteoradionecrosis. In the CAD-CAM denture group, 11 RCDs were fabricated by using the DDS-AV system, and 5 dentures were fabricated by using the DD-IV system.

The median treatment duration for the CAD-CAM and conventional denture fabrication is given in Table 1. No significant differences were found between the 2 groups regarding the overall treatment duration (P=.978) and during T_0-T_1 (P=.889) or T_1-T_2 (P=.675). In addition, no significant difference was found in the treatment durations of the CAD-CAM systems DD-AV and DD-IV (median; IQR [days]) (period 1: 50.00; 26.00 and 40.00; 25.00, P=.641, period 2: 11.00; 22.00 and 14.00; 8.00, P=.807, period 3: 68.00; 43.00 and 74.00; 50.00, P=.642).

Table 1 shows the median number of areas of excessive pressure removed, relines, and repairs during T_2-T_3. No significant differences were found between CAD-CAM and conventionally manufactured RCDs regarding the duration of T_2-T_3, with a median duration of 99; 283.5 for CAD-CAM RCDs and 207; 169.5 for conventional RCDs (P=.757). While comparing the 2 digital manufacturing systems, no differences were found regarding modification needs in T_2-T_3 (areas of excessive pressure removed; 0.00; 0.50 and 0.00, P=.757, no relines, and no repairs P=1.000).

Significant differences were found between CAD-CAM (d) and conventionally (c) manufactured RCDs in terms of laboratory and total costs (USD) (clinical treatment costs; CI-d [$1111-$2515]/CI-c [$1409-$2633] P=.060, laboratory costs; CI-d [$926-$1591]/CI-c[$1821-$2190] P=.001, total costs; CI-d [$2791-$4106]/CI-c [$3864-$4824] P=.011). No difference was found on analyzing the clinical treatment costs. The costs for the DD-IV RCDs were significantly higher than those for DDS-AV (clinical treatment costs; CI [$2626-$3186]/CI [$1111-$2867] P=.013 (Fig. 1A), laboratory costs; CI [DD-IV] [$1632-$1839]/CI [DDS-AV] [$926-$2312] P=.036 (Fig. 1B), total costs; CI [DD-IV] [$4258-$4692]/CI [DDS-AV] [$2792-$3840] P=.003) (Fig. 1C). In addition, the costs for conventional RCDs were higher than those of the DD-IV system.

The number of clinical and follow-up visits in all 3 periods was compared between the conventional and CAD-CAM groups (Fig. 2). Neither the comparison of the conventional compared with the CAD-CAM groups (P=.945) nor the comparison between both CAD-CAM groups DDS-AV and DD-IV (P=.848) revealed any statistical significance. Furthermore, the interaction between groups and periods between conventional and CAD-CAM (P=.083) and both CAD-CAM groups (P=.171) showed no significant differences. Only the comparison of the number of clinical visits within the period showed any significance (P<.001) when T_0-T_1 and T_2-T_3 were compared, with T_2-T_3 requiring significantly fewer clinical visits.

DISCUSSION

This retrospective study evaluated the clinical and economic outcomes of conventionally and CAD-CAM–fabricated RCDs in a university clinic. No significant differences regarding treatment duration or post-RCD delivery adjustments were found between CAD-CAM and conventional RCDs, confirming this part of the null hypothesis. In terms of the treatment costs, the null hypothesis was rejected, as the overall and dental laboratory costs were lower when the RCDs were fabricated by using a CAD-CAM system.

Generally, the treatment duration can be assessed by the number of clinical appointments, the clinical chairside time, or the number of days needed for treatment. A reduced number of appointments have been reported for CAD-CAM than for conventional RCDs.[7,8,13] Therefore,

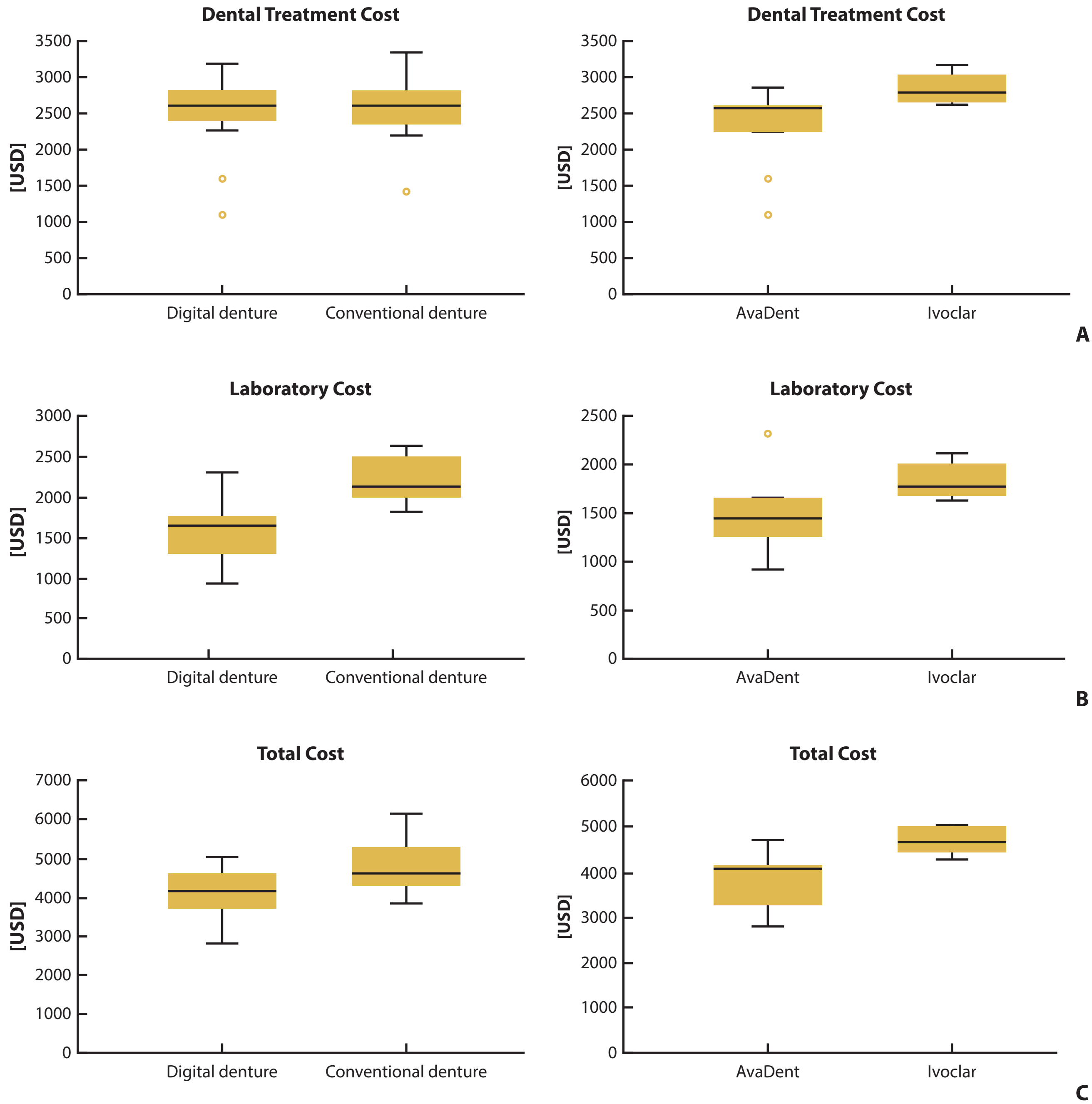

Figure 1. Box plots of costs in United States dollars comparing conventional and digital groups or 2 different digital RCD groups (AvaDent Digital Dental Solutions and Wieland Digital Denture system). A, Treatment costs. B, Laboratory costs. C, Total costs. *P* values of conventional to digital RCD *P*=.596; and digital RCDs *P*=.013. IQR, interquartile range; Q1, first quartile; Q3, third quartile; RCD, removable complete denture. Outliers: Q1 - 1.5*IQR and Q3 + 1.5*IQR.; ▯: IQR (Q3-Q1), —: Median, ǀ:Nonoutliner range, ∘: Outliers

the present analysis focused on the number of days which was needed for RCD fabrication. Although this kind of analysis includes the variations in patient, dental laboratory technician, and clinician availability, it represents clinical practice more realistically than focusing on the number of appointments, which might also explain the contradictory results of the present study compared with previous results.[7,8,13] Although CAD-CAM RCDs might be fabricated more rapidly than conventional RCDs, the current results demonstrated that this benefit only partly considers that CAD-CAM RCDs external milling centers are part of a complex production chain. However, the fabrication periods of most CAD-CAM RCDs were shorter than those in the conventional RCD groups except for 1 prosthesis for which several clinical evaluations were performed to address high patient expectations. The chairside time could

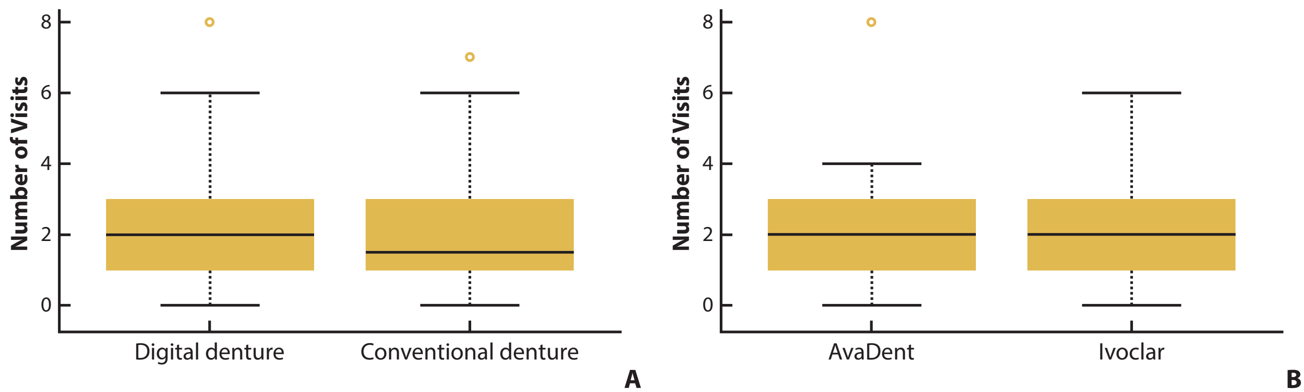

Figure 2. Box plots of total clinical and follow-up visits. A, Comparing conventional and digital dentures. B, Comparing 2 digital RCD groups (AvaDent Digital Dental Solutions and Wieland Digital Denture system). *P* values of conventional to digital RCD *P*=.945; and 2 types of digital RCDs *P*=.848. IQR, interquartile range; Q1, first quartile; Q3, third quartile; RCD, removable complete denture. Outliers: Q1 - 1.5*IQR and Q3 + 1.5*IQR; ▯: IQR (Q3-Q1), —: Median, ᑊ:Nonoutliner range, ∘: Outliers

not be analyzed because of the retrospective character of the study.

Most studies on the material and mechanical properties of CAD-CAM RCDs have reported improved fit and increased retention of the CAD-CAM RCDs.[14,16-18] Both factors might be accompanied by reduced areas of excessive pressure in the early RCD adaptation phase. In the present study, no difference was found in the number of post-RCD delivery adjustments between the 2 different RCD fabrication methods. Therefore, it can be presumed that CAD-CAM RCDs might not have increased risk of follow-up adjustments. One study reported an average of 3.3 denture adjustments after insertion of CAD-CAM dentures.[19] The lower number of adjustments in this study might be because the RCDs were new prostheses instead of a duplication of the existing denture.[19] The CAD-CAM and conventional RCDs were all made by the same dental laboratory technician, who was experienced with all the systems used in this study, leading to high comparability of the different kinds of RCD-manufacturing procedures. However, the results may have been different if a less-experienced team had fabricated the RCDs.

Studies comparing the treatment costs of CAD-CAM and conventional RCDs are sparse. A study reporting on the AvaDent System compared its cost with the cost of a conventional complete RCD protocol in the university setting of a predoctoral student clinic. There, the laboratory fees and total costs for the patients were significantly lower for CAD-CAM RCDs than for conventional RCDs.[12] In the present study, the treatments were performed by experienced prosthodontists and showed similar results to those of the study by Srinivasan et al[12] regarding time and cost estimations of CAD-CAM–milled removable complete dentures.

Comparing the CAD-CAM with conventional RCDs in terms of treatment costs including dentist's fees and materials showed no significant differences in the present study. The CAD-CAM RCD treatment process involves some clinical steps that are performed in a single visit by applying similar clinical methods and materials compared with conventional RCD treatment. Therefore, the treatment costs for CAD-CAM and conventional RCD fabrication were similar. However, laboratory costs for CAD-CAM RCDs were lower than those of conventional RCDs, as previously reported.[12] Several manual steps during conventional RCD fabrication can be replaced by machine processes for CAD-CAM RCDs, saving time for the dental laboratory technician and consequently leading to a reduction in cost.

Comparing the 2 applied digital systems, clinical treatment costs, laboratory costs, and total costs were significantly higher when using the DD-IV than using the DDS-AV system. Manufacturing RCDs with DD-IV comprised more clinical steps than DDS-AV, which might affect the clinical costs. The lower laboratory costs of DDS-AV RCDs could be explained by the lack of the clinical evaluation step compared with the DD-IV dentures. The results lower than the median for the treatment cost of the DDS-AV group can be explained by patients receiving immediate RCDs.

Limitations of this study included the retrospective design, which restricted the outcome measurements, the different numbers of patients treated with DDS-AV and DD-IV, and the small sample size. RCDs were provided in various clinical situations, but both groups included the same number of patients with altered anatomy and function after treatment for oral cancer. Nevertheless, the patient pool represented realistic conditions encountered in clinical practice. The 2 different digital denture systems were merged because of the limited patient numbers. Nevertheless, both digital systems were studied separately in terms of costs, postdelivery adjustments, and treatment periods.

The cost analyses performed in this study are based on the fabrication costs for RCDs in Switzerland. Therefore, the findings should be interpreted accordingly, as costs are specific to the region or country. Compared with the United States, laboratory fees are significantly higher in Switzerland, and even lower digital laboratory costs would be expected in many regions.

Elderly patients, who represent most edentulous patients, may have difficulties attending dental appointments because of general health problems and might significantly benefit from the reduced number of clinical visits and simplified procedures. Furthermore, the reduction of the expenses for fabricating RCDs makes RCDs financially more accessible. With further improvement of digital intraoral scanning, traditional impression making during the clinical appointments may be replaced, resulting perhaps in further reduction in the overall treatment costs. Therefore, CAD-CAM treatments in terms of removable RCD fabrication are expected to provide a viable alternative to conventional manufacturing methods. However, prospective clinical studies on CAD-CAM treatment protocols are necessary to provide evidence for this type of intervention.

CONCLUSIONS

Based on the findings of this retrospective clinical study, the following conclusions were drawn:

1. CAD-CAM and conventional complete RCDs required a similar number of treatment adjustments.
2. However, digital treatment was less expensive in terms of overall costs, laboratory costs, and fewer clinical visits, suggesting that digital complete RCDs might replace conventional complete RCDs, reducing clinical treatment time and costs.

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